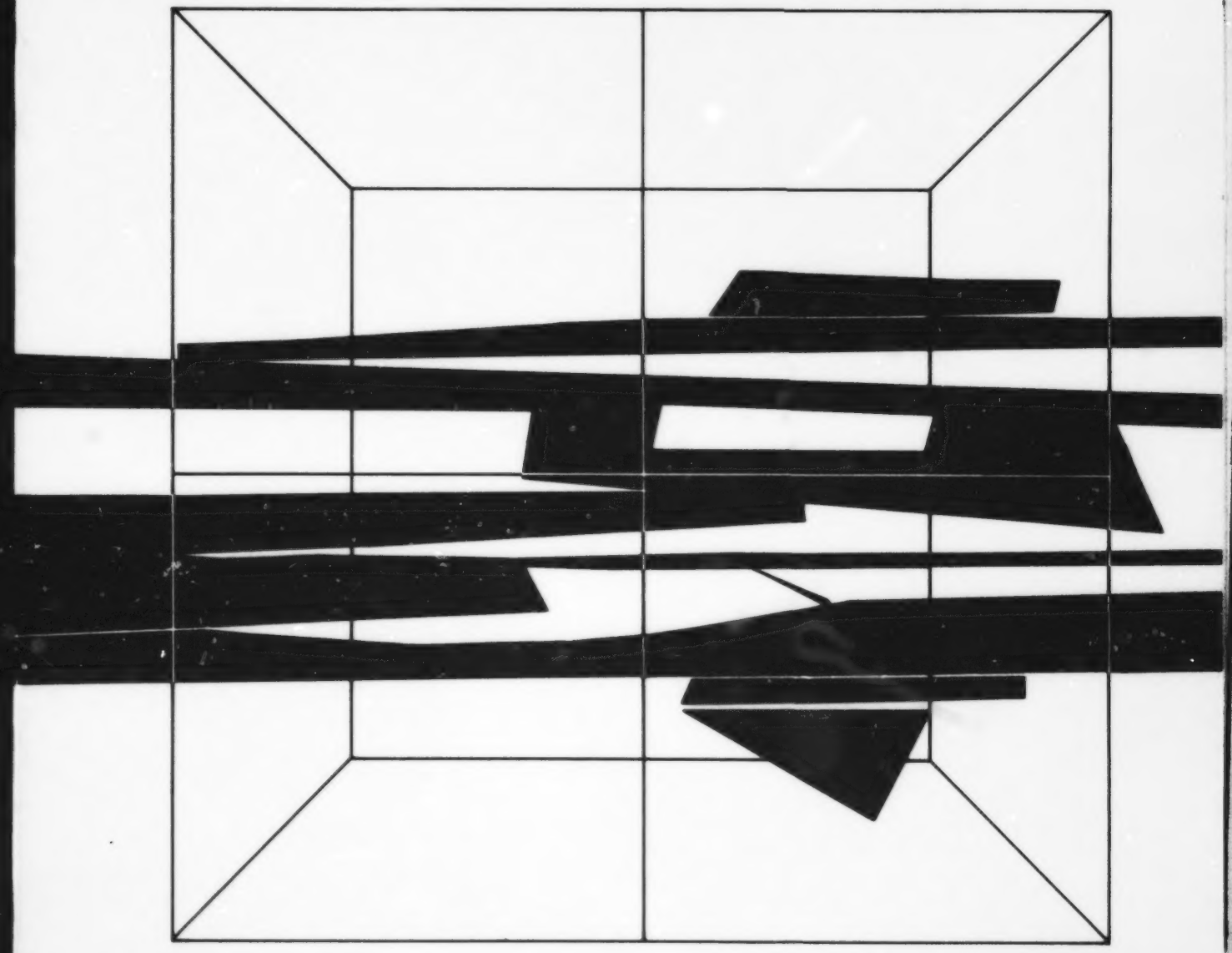
Implications of Reduced and No-tillage Systems on Chemical Use in the Prairie Provinces

Report EPS 4/AG/1
August 1985



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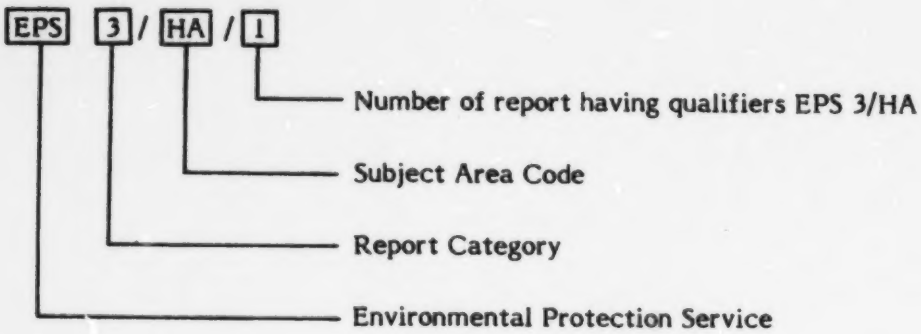

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IMPLICATIONS OF REDUCED AND NO-TILLAGE SYSTEMS ON CHEMICAL USE IN THE PRAIRIE PROVINCES

by
A.A. Aquatic Research Limited

for the
Western and Northern Region
Environmental Protection Service
Environment Canada

Report EPS 4/AG/1
August 1985

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ABSTRACT

This study was initiated to obtain background information on the implications of reduced and no-tillage systems on chemical use in the prairie provinces.

The study revealed that very few reduced and no-tillage systems exist in the prairie provinces. The high cost of herbicides and the need for improved farm management have been cited as the limiting factors. The southern regions of the prairie provinces have the greatest potential for reduced and no-tillage farming. Changing from conventional to a reduced or no-tillage system causes a shift in the weed spectrum that favours the growth of perennial weeds. The use of herbicides is expected to increase with reduced and particularly no-tillage systems; postemergence herbicides capable of controlling perennial weeds will likely exhibit the greatest increase.

Reduced and no-tillage systems substantially reduce soil erosion by wind and water. As a result, the transport of nutrients and herbicides from the target areas to the surface waters is greatly reduced compared to conventional tillage.

Adopting reduced or no-tillage systems instead of maintaining the conventional system has great potential in maintaining or improving soil fertility, and reducing farm operational costs.

RÉSUMÉ

L'étude a été entreprise pour obtenir des données de base concernant l'effet de l'application de procédés culturaux avec réduction du labourage ou sans labourage sur l'utilisation des produits chimiques dans les Prairies.

On a constaté que ces procédés étaient très peu employés dans les Prairies en raison du coût élevé des herbicides et de la nécessité d'améliorer la gestion agricole. Le sud de ces provinces offre le plus de possibilités d'application des procédés en question. L'abandon des méthodes classiques de culture provoque un changement dans la variété des mauvaises herbes qui favorise la croissance des plantes vivaces. On prévoit que l'emploi de ces nouveaux procédés fera augmenter l'utilisation d'herbicides, notamment ceux qui servent aux traitements de post-émergence et qui peuvent éliminer les plantes vivaces.

Les procédés mentionnés réduisent considérablement l'érosion du sol par l'eau et le vent. Par conséquent, la quantité d'éléments nutritifs et d'herbicides transportés vers les eaux de surface est beaucoup moins grande qu'elle ne le serait si le sol était cultivé de façon classique.

L'adoption de procédés culturaux avec réduction du labourage ou sans labourage peut grandement aider à maintenir ou à augmenter la fertilité du sol et à réduire les coûts d'exploitation agricole.

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1 INTRODUCTION

Tillage is one aspect of farming that is being studied in research and development efforts to increase crop production and reduce operating costs while maintaining or improving soil fertility. Farmers have long sought new procedures of crop production and new labour saving devices for tillage. Now, chemical and mechanical innovations are challenging the concept of tillage. An improved selection of chemicals for weed control has aided in bringing about reduced tillage and no-tillage systems that are part of a conservation tillage concept. These systems have gained worldwide attention and show some application in the prairie provinces (Alberta, Saskatchewan and Manitoba).

The current assumption is that increases in reduced tillage or no-tillage practices result in increased use of chemicals for weed and pest control. Chemicals of particular concern are those which may contaminate the aquatic environment, because of the potential for widespread environmental damage.

1.1 Objectives

The objectives of the study were:

1) to identify regions and crop types in the prairie provinces that are most conducive to reduced tillage or no-tillage farming systems;
2) to describe the current status and trends of reduced and no-tillage systems in the prairie provinces;
3) to describe the effects of reduced and no-tillage systems on chemical use as compared to conventional tillage practice, including:
   - describing shifts in weed, pest and plant disease spectra associated with reduced and no-tillage systems,
   - identifying the chemicals currently used in reduced and no-tillage systems and their general characteristics,
   - outlining future trends for chemical use and chemical types associated with reduced and no-tillage systems, and
   - describing the seasonal application of chemicals used; and
4) to describe the main environmental factors associated with chemical use in reduced and no-tillage systems.

1.2 Study Methods

At the outset, a computer-assisted literature search was conducted, with emphasis on the prairie provinces, and on the corn-belt region of the United States. Much of the knowledge on tillage practices and chemical use (with associated environmental effects) has been developed in the United States. The information obtained on trends in the United States was compared with developments in the prairie provinces. Since some parameters (crops, weeds and climate) are different in the United States from those in the prairie provinces, precautions were taken to ensure that the information used for comparison was pertinent. The databases that were searched are listed in Table 1.

TABLE 1 DATABASES

System	Data Period	Producer
DIALOG-Agricola	1970 to present	U.S.D.A. National Agriculture Library
CAN/OLE-ICAR (Inventory of Agricultural Research)	ongoing research projects	Canadian Agricultural Research Council
QL SYSTEMS - Canadian Plains Research Inventory	1975 to present	Canadian Plains Research Centre

The literature search yielded approximately 750 titles or abstracts, of those, 700 originated from the Agricola database.

Subsequently, government agencies and universities in Alberta, Saskatchewan and Manitoba were contacted by telephone to obtain additional information. In addition, meetings were held with researchers who were actively involved with tillage practices. The agencies, persons contacted, and mode of contact are outlined in Table 2.

TABLE 2 INFORMATION CONTACTS

Agency	Person	Mode of Contact
Alberta		
University of Alberta (Edmonton)	Dr. B. Vandenborn Prof. Plant Science	telephone
Alberta Agriculture (Edmonton)	Mr. A. Goettel Head, Soils Branch	telephone
Alberta Agriculture (Edmonton)	Mr. K. Price Head, Crop Protection Branch	meeting
Agriculture Canada (Lacombe)	Dr. A. O'Sullivan Research Scientist	meeting
Agriculture Canada (Lethbridge)	Dr. W. Lindwall Tillage Engineer	meeting
Agriculture Canada (Lethbridge)	Mr. Jim Moyer Weed Control Specialist	meeting
Saskatchewan		
University of Saskatchewan (Saskatoon)	Dr. D. Rennie Dean of Agriculture	meeting
University of Saskatchewan (Regina)	Mr. K. Foster Research Scientist	meeting
Agriculture Canada (Scott)	Mr. K. Kirkland Weed Specialist	meeting
Agriculture Canada (Swift Current)	Dr. C. Campbell Researcher	telephone
Manitoba		
University of Manitoba (Winnipeg)	Dr. E. Stobbe Prof. Plant Science	meeting
University of Manitoba (Winnipeg)	Dr. E. Morrison Researcher	meeting
Manitoba Agriculture (Winnipeg)	Dr. B. Todd Chief, Weed Section	meeting

2 REDUCED AND NO-TILLAGE SYSTEMS

Reduced and no-tillage systems are forms of conservation tillage, but their exact definition varies among researchers. The following definitions are based mainly on those reported by Unger and McCalla (1980) and Crosson (1981).

Conservation tillage is a system of managing crop residue on the soil surface to prevent erosion and conserve moisture. Examples of conservation tillage are: reduced tillage, no-tillage, and chemical fallow.

Reduced tillage (or minimum tillage) is a system of limiting the number of tillage operations and selecting appropriate tillage implements in order to maintain crop residue on the soil surface. This implies the use of substitute techniques (including herbicides) for weed control or seedbed preparation.

No-tillage is a system in which a crop is planted directly into soil that has not been tilled since harvest of the previous crop; herbicides are used where necessary. Other synonymous terms are "slit plant", "slot plant", "sod plant" or "zero tillage".

Chemical fallow is essentially a substitution of herbicide applications for two or more tillage operations to control weeds in summerfallow. Chemical fallow is regarded as a form of reduced tillage in this report.

2.1 Status of Reduced and No-tillage Systems

Reduced tillage and no-tillage systems have been practised for approximately 30 years in the United Kingdom and United States. Their use began primarily as a soil conservation measure in dry areas of North America where soil losses on bare fields were severe due to wind erosion.

On the Canadian prairies, farmers have limited tillage operations by "stubbling in" and reducing the number of summerfallow operations by spraying, or by ploughing under clover or a green manure crop, and by improving tillage equipment (Alberta Agriculture, 1980). Availability of effective herbicides has aided the development of reduced and no-tillage cropping systems (Unger and McCalla, 1980). A further motive for implementing such practices is to reduce the high operating costs, especially with respect to fuel.

No-tillage is a recent system which has developed rapidly since the early 1960s (Phillips and Young, 1973). Factors such as erosion and economics, as well as additional food production from a fixed land resource base, have encouraged no-tillage development.

2.1.1 Reduced and No-tillage in the United States. Conservation tillage is becoming increasingly prevalent throughout the United States. The Corn Belt and Northern Plains have the largest acreages of reduced tillage, while no-tillage acreages are largest in the Corn Belt, Northeast and Appalachian regions (Christensen and Norris, 1983). A comparison of the increase in conventional tillage, no-tillage and reduced tillage systems in the United States is shown in Table 3. Christensen and Norris (1983) indicated that the major acreage shifts have been from conventional to reduced tillage systems, based on distribution of cropland by type of tillage system. The share of total cropland in conventional tillage systems increased less than one percent from 1973 to 1981, while the share in reduced tillage more than doubled. In 1981, the Southeast had 41 percent of its cropland in reduced tillage; while the Corn Belt, the Northern Plains, the Appalachian and the Mountain States each had at least 30 percent in reduced tillage. No-tillage is most common in soybean and corn production. Sixty percent of the United States 1982 corn crop was produced in a conservation tillage system, of which 8.4 percent was in no-tillage (King, 1983).

TABLE 3 INCREASE IN NO-TILLAGE AND REDUCED TILLAGE SYSTEMS IN THE UNITED STATES, FROM 1973 TO 1981

System	Acreage Increase
1. Conventional Tillage	1%
2. No-tillage	78%
3. Reduced Tillage	125%

No-tillage has been most successful for corn-meadow rotations in the humid regions of the southeastern United States. However, in the Corn Belt and many parts of the Great Plains region, including southern areas of the three prairie provinces, no-tillage has resulted in significantly lower yields than those from conventional tilled systems. The development of better planting equipment and more suitable herbicides will help overcome many of the problems associated with no-tillage (Lindwall, 1984). There appears to be little doubt that the trend towards reduced and no-tillage cropping systems will continue, but as most researchers indicate, these systems may have a viable future only in selected regions depending on such parameters as crop types, weeds, climate and soil conditions. Most researchers also agree that potential benefits of reduced and

no-tillage systems are too important to ignore, but several problems need to be resolved before the systems gain wide acceptance. The greatest immediate concerns to farmers seem to be the economic feasibility of replacing tillage with herbicides, the necessity of specialized seed equipment and the farmers management ability (Lindwall, 1984).

The use of conservation tillage systems in the United States will continue but will require more careful management by farmers than conventional tillage systems (Kelly, 1977). By the year 2000, it is estimated that 80 percent of the planted croplands in the United States will be in reduced and no-tillage systems; of that, 45 percent will be in no-tillage (Lindwall; Stobbe, pers. comm.). The availability of planting equipment, chemicals and reduced farm labour have accelerated the use of the no-tillage system. Phillips and Phillips (1984) indicated that, of the philosophies developing in the introduction and expansion of no-tillage, one trend is to consider the use of no-tillage on the more productive soils and to maximize yield through no-tillage manipulation.

2.1.2 Reduced and No-tillage in the Prairie Provinces. The extent (area and degree of tillage reduction) of reduced tillage cropping systems in the prairies is difficult to describe because the description is dependent on the basis of comparison. For example, since the introduction of 2,4-D herbicide in 1940, most farmers in the prairies have reduced the number of tillage operations to some degree through better farm management and the use of herbicides. In the last ten years, however, additional reduction of the number of tillage operations through substitution with herbicides has been limited. For this period, documented information on the areas and degree to which tillage operations have been reduced is not available (Lindwall; Hunter; Stobbe, pers. comm.).

In the last twenty years, most of the long-term research on tillage has been conducted at Swift Current and Melfort, Saskatchewan and Lethbridge, Alberta. Summerfallow continues to be practised on more than ten million hectares in the prairie provinces despite widespread controversy regarding its use. Yet the acceptance of reduced tillage and no-tillage systems, particularly no-tillage, by farmers in the prairie provinces has been limited. Reduced tillage offers the farmer greater flexibility than no-tillage and is more likely to be adopted (Lindwall, 1984). Despite that, the acceptance is influenced by simple economics; the high cost of herbicide relative to the cost of tillage operations.

The most important advantage of reduced and no-tillage practices, as compared to conventional tillage, is improved soil conservation. Currently the greatest benefit from implementing these systems is gained in the regions where rainfall is limiting

crop production, such as those associated with the Dark Brown and Brown soil zones of south-central Alberta and Saskatchewan, and in the Black Chernozemic soil zone of southwestern Manitoba (Lindwall; Hunter; Stobbe, pers. comm.). The advantages of reduced tillage, in particular, can be extended to other regions of the provinces, including some north-central regions where canola is grown (Rennie, pers. comm.).

Alberta. In Alberta the practice of reduced tillage, which includes the use of herbicides as a substitute for tillage, is limited. Application of a herbicide in the fall as a substitute for tillage is uncommon and limited only to spot spraying (O'Sullivan, pers. comm.). The use of a herbicide in the spring prior to seeding is also uncommon, herbicides are generally incorporated with the spring seeding operation. The chemical fallow system has been researched but, despite favourable agronomic results, the high cost of repeated applications of herbicides makes the system uneconomical (Lindwall, 1984).

No-tillage is currently employed on a permanent basis by about eight farmers, mainly in the southern region of the province. Approximately thirty thousand hectares are involved with an additional one hundred farmers using no-tillage in a crop rotation (Lindwall, pers. comm.). Some three hundred farmers, who are proponents of the no-tillage system, make up the Alberta Farmers Conservation in Crop Production Association. Winter wheat, which appears to be well suited to a no-tillage system, makes up most of the area associated with no-tillage, followed by spring wheat, barley and canola. Currently, researchers are studying the feasibility of using the no-tillage system in the Peace River region as an aid in reducing water erosion.

Saskatchewan. Rennie (1984) reported that approximately 40 percent of all cultivated land in Saskatchewan has been summerfallowed annually since 1960. He predicts that a reduced tillage system will become more prominent reducing the eight million hectares currently summerfallowed to approximately four million hectares, while increasing the total area under cultivation from about ten to thirteen million hectares. Despite the problems associated with summerfallowing the practice of reduced tillage is limited in Saskatchewan. Fall application of herbicides as a substitute for tillage is most prevalent in the southwest, very limited in the north-central, and non-existent in the southeast (Hunter, pers. comm.). Disc seeding prevents the use of herbicides in spring prior to seeding. Chemical fallow is an uncommon practice. In Saskatchewan, farmers exercise a great deal of flexibility in crop rotation and generally a winter wheat crop becomes part of the reduced tillage operation.

Approximately 10 000 hectares, mainly located in the southern region of the province, are under a no-tillage regime (Foster, pers. comm.). Winter wheat and spring wheat followed by barley and canola appear to be the main crops chosen by farmers practising no-tillage in this area (Hunter, pers. comm.).

Manitoba. In Manitoba tillage has been reduced to a degree where approximately 20 percent of the total cropland is summerfallowed (Morrison, pers. comm.). The reduced tillage system has been mainly achieved through crop rotation; chemical fallow is not used in Manitoba. Wheat, barley, oats, flax, canola, sunflower, corn, buckwheat, lentils, sugar beets, peas, and soybeans are associated with the reduced tillage system. This generally includes fall and spring (prior to seeding) application of herbicides; there is a shift away from spring tillage (Todd, pers. comm.).

Approximately 10 000 hectares, mainly located in the southwestern region of the province, are currently under no-tillage practice (Morrison, pers. comm.). Spring wheat followed by winter wheat, barley and oil crops are the main crops associated with a no-tillage system (Todd; Stobbe, pers. comm.).

3 EFFECTS OF REDUCED AND NO-TILLAGE SYSTEMS ON CHEMICAL USE

3.1 Weed Control

Weed control is achieved by either tillage, herbicide application, cultural means (i.e., crop rotation) or by combinations of these farming methods. When a particular method or combination is chosen, certain weeds are favoured (Arnold, 1976; Fenster, 1977; Stobbe, 1978; Burnside, 1980). Arnold (1976) reported that conservation farming systems on the Northern Great Plains of the United States favour the perennial weeds such as quackgrass and Canada thistle. Phillips and Phillips (1984) also found that annual grasses were favoured by reduced cultivation, while perennial species were more prevalent under no-tillage.

Researchers agree that in the Canadian prairies reduced tillage and particularly no-tillage systems favour the growth of perennial weeds (O'Sullivan; Lindwall; Hunter; Stobbe, pers. comm.). Stobbe explained that, in Manitoba, the shift in the weed spectrum associated with reduced tillage is not substantial. Similarly in some American reduced tillage operations the weed spectrum and infestation levels were not different from conventional tillage (Jacques, 1983).

In the prairie provinces, weed problems associated with reduced and no-tillage systems that cannot be controlled with herbicides are not anticipated, although Stobbe (1978) reported concern with wild barley and wild rose. In the United States some reduced tillage operations revealed a shift to vines and woody plant species that may not be controlled by herbicides (Jacques, 1983). There will be instances where herbicides cannot be a substitute for tillage practices (Antognini, 1983).

3.1.1 Chemical Use. Reduced and no-tillage systems generally result in increased chemical use and a shift in the type of chemicals used. This reflects changes in the weed spectrum from that of the conventional tillage system.

Crosson (1981) reported that there are a number of reasons why reduced systems may require the use of more herbicides than conventional systems and why no-tillage definitely does. The main reason is substitution. If control by tillage is reduced, then a compensatory increase in the amount of herbicide applied is necessary to maintain the same level of control. A second reason is efficacy. More herbicide must be applied because some herbicide gets tied up in crop residue. A third reason is the environmental effect. More herbicide is required because, as compared to conventional tillage, reduced

and no-tillage systems retain higher moisture levels resulting in improved conditions for germination and growth of weeds.

Christensen and Norris (1983) reported that converting from conventional to no-tillage corn production increased the use of herbicides by 43 percent. It should be noted that although increased chemical use is associated with reduced and no-tillage systems, the term "increased" can be interpreted in various ways, including cost of herbicide, total amount of all herbicides used or weight of active ingredient applied per unit area. Jacques (1983) reported that the weed spectrum associated with the reduced tillage system may not differ from conventional tillage; therefore, the herbicide requirements should not be appreciably altered. Researchers in the prairie provinces agree that, although use of herbicides associated with the no-tillage system increases, the relationship between herbicide use and reduced tillage is not as clearly defined (O'Sullivan; Hunter; Stobbe, pers. comm.). It is perhaps more appropriate to assume that as the number of tillage operations are reduced in a given farming operation, the use of certain types of chemicals may increase. Worsham (1983) indicated that at planting time in nearly all reduced tillage systems in the United States, a contact herbicide such as paraquat or a fast acting, translocated herbicide such as glyphosate was needed along with a residual herbicide for controlling weeds or a cover crop; after that, use of postemergence herbicides was similar to conventional systems. He found that the increased use of a residual herbicide in a no-tillage system was rarely required and that need for a postemergence herbicide was reduced.

In the prairie provinces, herbicides currently used in reduced and no-tillage systems are the same as those used for conventional systems, except some are more favoured than others (Lindwall; Hunter; Stobbe, pers. comm.). In reduced and no-tillage systems there is an increased reliance on postemergence herbicides, since soil incorporated herbicides are less applicable with reduced tillage and not applicable with a no-tillage practice.

In Alberta and Saskatchewan where reduced tillage and chemical fallow is practised, winter annual weeds are controlled with 2,4-D in fall and early spring, eliminating or delaying the need for cultivation on summerfallow until May or early June. Sweep• (paraquat) can also be used for non-selective control of grasses and volunteer grain on summerfallow (Alberta Agriculture, 1980). Where broadleaf weeds are also a problem, 2,4-D, Pardner• (bromoxynil) plus MCPA, Banvel• (dicamba) plus 2,4-D, or Lorox• (linuron) plus MCPA as a mix with Sweep• or as a separate application, are used. Glean• (chlorsulfuron), a postemergence herbicide used in wheat and barley crops,

is also applicable in reduced tillage systems to control perennial weeds. The use of Glean•, though, is limited because its residue is toxic to other crops that may be part of a crop rotation. Recently, Poast• (sethoxydim) and Fusilade• (fluazifop-butyl) have also become favourable herbicides in a reduced tillage system to control annuals mainly in canola and flax crops (Hunter; O'Sullivan, pers. comm.).

In Alberta and Saskatchewan, the postemergence herbicides used in a no-tillage system are similar. In fall, mixtures of Banvel• plus 2,4-D, MCPA, Roundup• (glyphosate) or Amitrol• (amitrole) are generally used for controlling perennial weeds. Winter annuals are controlled in the fall by applying 2,4-D or Banvel• plus phenoxy; volunteer grains are controlled by Roundup•. Prior to or immediately after seeding, Roundup• or Sweep• are most commonly used; for control of wild buckwheat Torch• (bromoxynil) can be added to Sweep• (Alberta Agriculture, 1980).

In Manitoba, because of an extensive crop rotation, the selection of herbicides is slightly different than that of Alberta and Saskatchewan. In fall, either Roundup•, 2,4-D, or 2,4-D plus Banvel• are used (Todd, pers. comm.). Todd explained that increases in winter wheat production will likely result in increased use of Buctril M• (bromoxynil + MCPA) for control of winter annuals.

Prior to or immediately after seeding, either Roundup•, Roundup• plus Torch•, Roundup• plus Pardner• or Sweep• are used. Glean• is not used because its residual in the soil is toxic to other crops in the rotation.

Roundup•, Sweep• and 2,4-D are the main herbicides used in reduced and no-tillage systems (Hunter, pers. comm.). It should be noted that the high cost of some herbicides prevents their wide use and their efficacy. Roundup• is particularly favoured because of its effectiveness on perennial and annual weeds, acute mammalian toxicity (oral LD_{50} rats = 4320 mg/kg), and its deactivation upon contact with the soil (Alberta Agriculture, 1984). Sweep• provides immediate, fast, and virtually complete annual grass control on summerfallow. An attractive feature is that it binds immediately to the soil and becomes biologically unavailable. Paraquat, the active ingredient in Sweep•, is very toxic, with an oral LD_{50} to rats of 120 mg/kg of body weight. Acute toxicity may also result from inhalation and dermal exposure to the spray mixture. Alberta Agriculture (1984) reported that 2,4-D under normal use conditions does not pose a leaching problem. It too has a high acute mammalian toxicity of 110 to 300 mg/kg (oral LD_{50} rats) for various formulations.

Development of herbicides that are environmentally safe and highly effective against weeds is the objective of many agricultural researchers. Antognini (1983)

reported that there are two major technological breakthroughs that will have a significant impact on reduced and no-tillage systems. The first is the advent of postemergence grass herbicides such as Poast• and Fusilade• which control practically all annual and perennial grasses in broadleaf crops. The second is a reduction of spray volumes by using vegetable oil as a carrier.

Researchers agree that it is difficult to ascertain a desirable residence time that herbicides should or will have in the future in the prairie crops. Ultimately, the most desirable herbicide is one that has a long residence time in the soil yet does not hinder crop rotation. It has been suggested that future herbicides will be characteristic of Glean•, because of its low application rates (Todd, pers. comm.). Lontrel• (clopyralid), not yet registered in the prairie provinces, may have a major role in controlling some annual and perennial weeds in canola crops grown in reduced and no-tillage systems (Todd, pers. comm.). Lontrel• is not mobile in typical prairie soils and the carry over into the year after treatment is low. Speculatively, the trend is towards herbicides that leave low residual levels in the soil based on the wide acceptance of Roundup• by farmers and the development of Fusilade•.

3.2 Pest and Disease Control

Insect and crop disease problems are more likely with reduced and no-tillage systems than conventional tillage because the crop residues left on the soil surface provide a favourable habitat for various insects and diseases (Crosson, 1981; Christensen and Norris, 1983; Fenster et al., 1977; and Phillips and Phillips, 1984).

Crosson (1981) indicated that the likelihood and severity of problems varies with the crops grown. In the United States, feed grains, wheat, soybeans and corn have the most severe insect problems based on the amount of insecticide applied. Corn produced under no-tillage showed increased problems with soil insects such as cutworms, wireworms, rootworms, white grubs, seed corn beetle, and seed corn maggot. Above ground insects included armyworms, corn borers, stalk borers, flea beetles, and corn leaf aphids (Phillips and Phillips, 1984). Reduced tillage and particularly no-tillage systems increase the possibility of grasshopper infestations because overwintering eggs are not disturbed by tillage (Fenster et al., 1977). Research in eastern Canada indicated little or no crop yield reduction from insects or disease in reduced and no-tillage systems (Ketchenson, 1977).

Phillips and Phillips (1984) reported that increased disease problems associated with reduced tillage as compared to conventional tillage are minimal. They suggested

that improved moisture conditions associated with reduced tillage promote rapid growth and healthier plants which reduces severity of disease in many instances.

There is a paucity of documented information on insect and disease problems associated with reduced and no-tillage systems in the prairie provinces. Much of the research is dedicated to weed control and herbicides (Stobbe; Kirkland, pers. comm.). In the prairies, a reduction of tillage operations may result in increased problems with grasshoppers, pale western cutworms, wireworms, and corn borers (Kirkland; Stobbe, pers. comm.). Other insects such as bertha armyworm and red turnip beetle are serious pests in canola crops (Johnson, 1977). Increased problems with insects or disease are not evident in reduced and no-tillage operations on the prairies (Kirkland; Stobbe, pers. comm.). Both researchers explained that if crop rotation is maintained the increased problems with insects or disease should remain minimal, therefore, reduced and no-tillage systems should not result in any notable changes in the use of insecticides or fungicides.

4 ENVIRONMENTAL CONSIDERATIONS

The main environmental factors associated with reduced and no-tillage systems are soil erosion (wind and water) and surface runoff water quality. The ways these factors change from conventional tillage practices to reduced and no-tillage operations, and how these changes effect the environment, particularly the aquatic environment are discussed in this section.

4.1 Soil Erosion

In the Central and Northern Great Plains of the United States, soil erosion is mainly caused by wind (Moldenhauer et al., 1983; Phillips and Phillips, 1984). In the prairie provinces, soil erosion is also mainly caused by wind while erosion caused by water is of concern in only some regions (Hunter, pers. comm.). The environmental effects of wind erosion are numerous, the main effects are: loss of soil fertility; loading of waters with sediment nutrients, herbicides and insecticides removed from agricultural land; and air pollution. Researchers agree that reduced and no-tillage systems substantially reduce soil erosion, however, the degree to which soil is conserved is not well documented. Studies in the United States showed that wind erosion loss (weight/hectare) from land plowed and planted with corn was approximately sixty times higher than the loss from a no-tillage corn field during one severe wind storm (Phillips and Phillips, 1984).

Gard (1971) indicated that, according to studies conducted in the United States, rain storms cause 80 percent of the soil loss due to water erosion. Soil erosion by water and the associated transport of sediments, nutrients, herbicides and insecticides to surface water is a major environmental problem according to Wischmeier (1973). He reported that the reduction in soil erosion achieved through conservation tillage as compared to conventional tillage operations are widely varied. He also found that soil lost to water erosion was inversely related to the percentage of the soil surface covered by residue, and that surface cover was responsible for 85 to 90 percent of the reduction in erosion. Most studies show that conservation tillage reduces erosion by water 50 to 90 percent more than conventional tillage (Crosson, 1981).

4.2 Surface Runoff Water Quality

The movement of soil nutrients, applied fertilizers, herbicides and insecticides from cultivated land to surface waters are a concern of farmers and environmental scientists. These chemicals can be transported as dissolved fractions in water or adsorbed

to soil particles (Crosson, 1981). Erosion by water is substantially less with reduced and no-tillage systems; a clear advantage over conventional tillage. Baker and Laflen (1983) reported that conservation tillage reduces transport of chemicals (nutrients and herbicides) to surface waters by affecting both the volume of runoff and the chemical concentrations in runoff water. They also indicated that, more importantly, conservation tillage reduces the transport of soil, and as a result, less chemical is transported to water bodies. It is unclear whether nitrate-nitrogen losses in runoff are more or less with conservation tillage than with conventional tillage. Crosson (1981) also indicated that the amount of available phosphorus transported to water bodies by eroded soil is less with conservation tillage, but the amount dissolved in runoff water is likely to be more. The transport of herbicides dissolved in runoff water and the potential for contamination of surface waters is highest when rain falls within a few hours after the herbicide application. The total movement of herbicide is almost negligible in a no-tillage system (Hayes, 1983).

Herbicide drift sometimes damages crops in neighbouring fields. This problem is more likely to occur using conservation tillage techniques which require a greater number of herbicide applications than conventional tillage systems. In the prairie provinces, documented information on the transport of pesticides associated with reduced and no-tillage systems are not available.

Most researchers express cautious optimism regarding the potential environmental effects associated with the herbicides that are or will be used in reduced and no-tillage systems, although any introduction of chemicals to the environment should be of concern. Research efforts continue to develop environmentally safer herbicides, but even with such herbicides as Roundup®, most researchers appear uncertain as to its possible environmental effects. It is evident that reduced and no-tillage systems can substantially decrease the transportation by wind or water of chemicals from agricultural lands to surface waters. This can be regarded as an important step in reducing the effects of chemicals on the aquatic environment. Worsham (1983) suggested that even if there is increased herbicide use associated with reduced and no-tillage systems, it is more environmentally sound than conventional tillage because the herbicides will remain in the target area.

In 1977 and 1978, a study conducted in southwest Manitoba revealed that a substantial increase in waterfowl productivity (ducks) could occur on the prairies with the widespread adoption of no-tillage systems (Cowan, 1982). An extrapolation of results

revealed an annual potential of 25 broods per 260 hectares on no-tillage farms compared to 7 broods per 260 hectares on conventional farms.

5 CONCLUSIONS

The study reveals that although the practice of reduced and no-tillage systems in the United States is substantial, with a continuing trend away from conventional tillage, the existence of these systems in the prairie provinces is limited. In the prairie provinces, the high cost of herbicides and the need for improved farm management have been cited as the limiting factors. By the year 2000, it is estimated that 80 percent of the planted cropland in the United States will be in reduced and no-tillage systems, of that, 45 percent will be in no-tillage.

Since the most important advantage is soil conservation, the greatest benefit from implementing reduced and no-tillage systems can be gained in the regions where rainfall is limiting crop production. Between ten and thirty thousand hectares of no-tillage is practised in southern regions of the prairie provinces.

Converting from conventional to reduced or no-tillage systems causes a shift in the weed spectrum that favours the growth of perennial weeds like Canada thistle and quackgrass. Mainly because of their substitution for tillage, the use of herbicides is expected to increase using reduced and in particular no-tillage systems. The use of postemergence herbicides capable of controlling perennial weeds will likely increase.

Reduced and no-tillage systems, mainly because of crop residue on the surface, can substantially reduce soil erosion by wind and water as compared to conventional tillage. Most studies show that conservation tillage systems reduce erosion from water by 50 to 90 percent compared to conventional tillage. The transport of nutrients and herbicides from target areas to surface waters, therefore, is greatly reduced.

No-tillage systems may provide improved waterfowl habitat resulting in larger number of broods per hectare than found in areas using conventional farming methods.

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